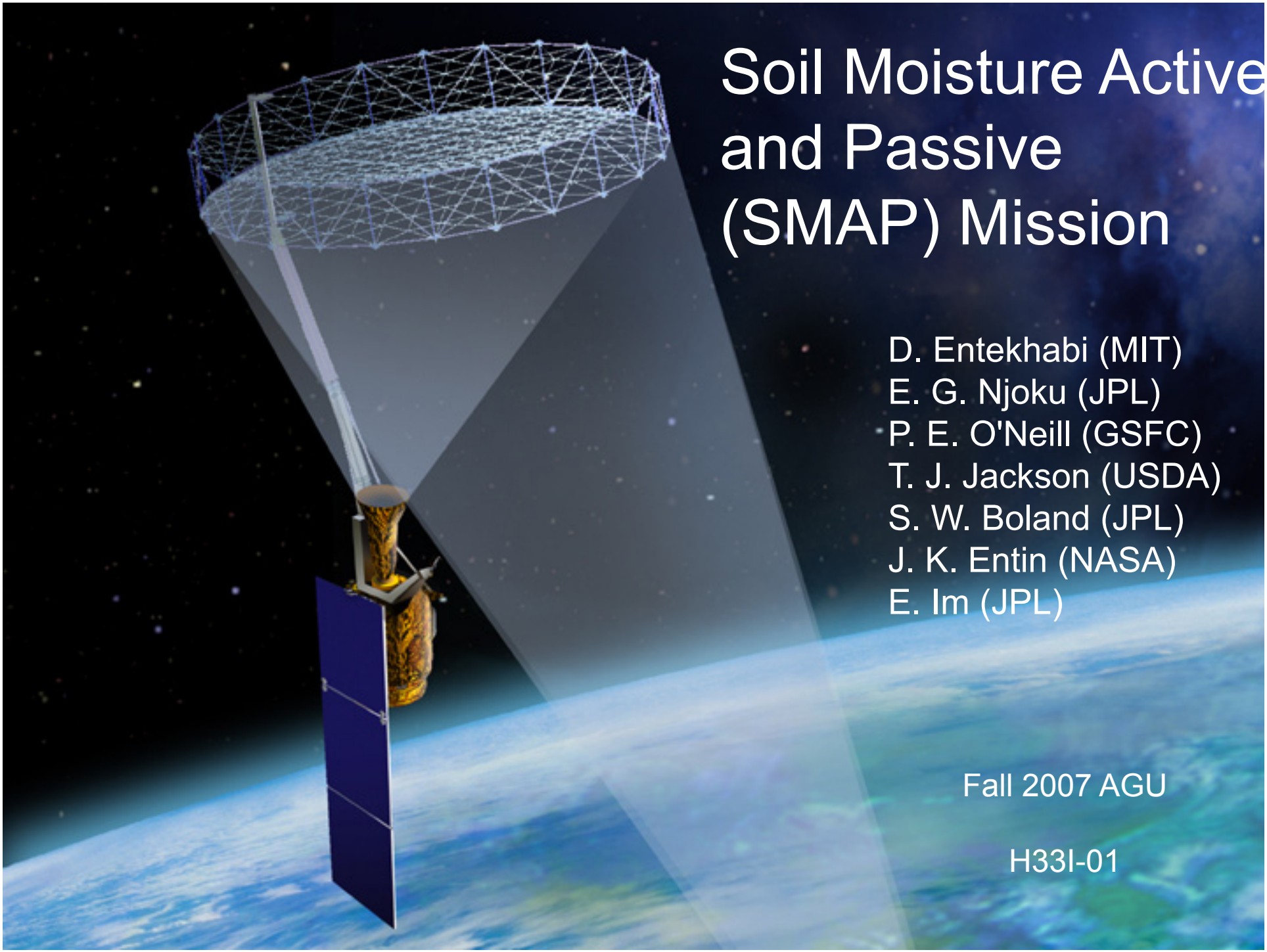

# Soil Moisture Active and Passive (SMAP) Mission

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Fall 2007 AGU

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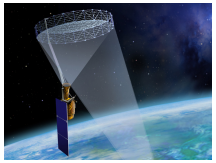
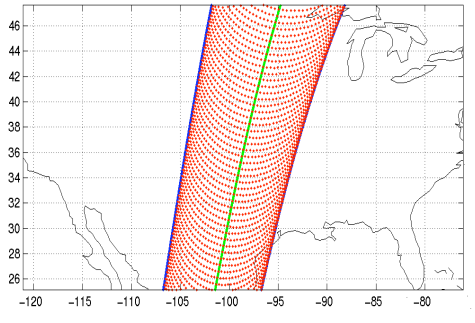


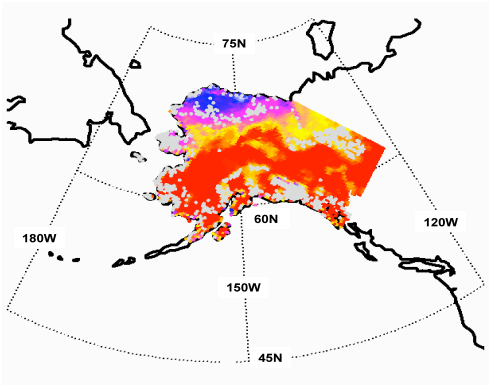
# SMAP Science Objectives

## SMAP is one of the four first-tier missions recommended by the NRC Earth Science Decadal Survey Report



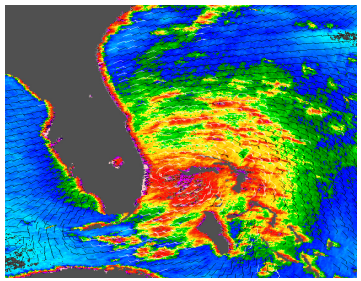

## Primary Science Objectives:

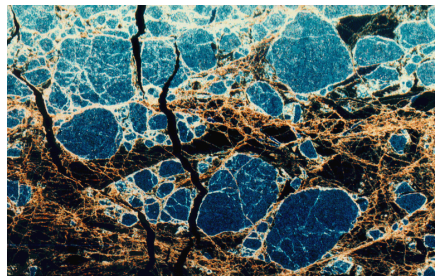
- Global, high-resolution mapping of soil moisture and its freeze/ thaw state to:
  - Estimate global water and energy fluxes at the land surface
  - Extend weather forecast skill
  - Develop flood and drought predictions
  - Quantify net carbon flux in boreal landscapes
  - Link terrestrial water, energy and carbon cycle processes

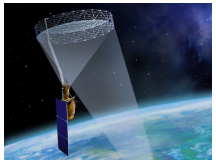



## Additional Science and Applications:

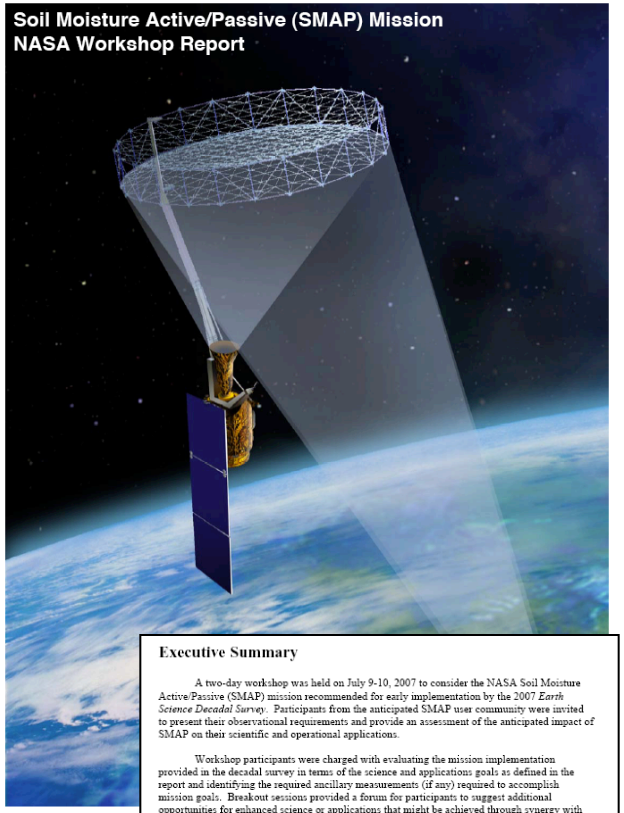
- NPOESS-era operational soil moisture (CMIS capability replacement and enhancement)
- Operational polar-ice monitoring (high-resolution, daily, all-weather)
- Vegetation growth and agricultural productivity estimates
- Ocean surface high-wind speed regime
- High-resolution sea surface salinity
- Heat stress and human health







# NASA SMAP Science Workshop (July 2007) and Report




**Executive Summary**

A two-day workshop was held on July 9-10, 2007 to consider the NASA Soil Moisture Active/Passive (SMAP) mission recommended for early implementation by the 2007 *Earth Science Decadal Survey*. Participants from the anticipated SMAP user community were invited to present their observational requirements and provide an assessment of the anticipated impact of SMAP on their scientific and operational applications.

Workshop participants were charged with evaluating the mission implementation provided in the decadal survey in terms of the science and applications goals as defined in the report and identifying the required ancillary measurements (if any) required to accomplish mission goals. Breakout sessions provided a forum for participants to suggest additional opportunities for enhanced science or applications that might be achieved through synergy with other planned missions and/or with augmentations to the SMAP mission.

Several key conclusions resulted from the workshop:

- There is a stable set of instrument measurement requirements for SMAP that are traceable to science requirements for soil moisture and freeze/thaw.
- The baseline SMAP instrument design is capable of satisfying the science measurement requirements.
- Significant heritage exits from design and risk-reduction work performed during Hydrosphere State (Hydros) mission formulation and other technology development activities. This heritage includes studies addressing science applications and algorithms, antenna rotation dynamics, antenna performance, and radio frequency interference mitigation techniques.
- Heritage and lessons learned can be leveraged from the Aquarius project. This heritage includes both the L-Band radiometer and radar electronics.
- There are no technology "show-stoppers," and SMAP formulation is positioned to begin where Hydros left off.

The importance and desirability of global soil moisture measurement from space was re-affirmed by workshop participants. There was general consensus that SMAP, as defined in the decadal survey and described in the NASA mission concept study, can accomplish the intended science. There was also general consensus that SMAP is well-defined, technologically feasible, and ready to be implemented on a "fast-track."

**Key Workshop conclusions (Executive Summary):**

- There is a stable set of instrument measurement requirements for SMAP that are traceable to science requirements for soil moisture and freeze/thaw.
- The baseline SMAP instrument design is capable of satisfying the science measurement requirements.
- Significant heritage exits from design and risk-reduction work performed during Hydrosphere State (Hydros) mission formulation and other technology development activities.
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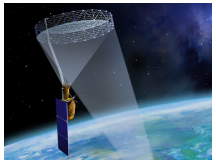
**http://hydrology.jpl.nasa.gov/missions/SMAP/**



# SMAP Science and Applications

| Decadal Survey Panels | Cited SMAP Applications |
|---|---|
| Water Resources and Hydrological Cycle | 1. Floods and Drought Forecasts<br>2. Available Water Resources Assessment<br>3. Link Terrestrial Water, Energy and Carbon Cycles |
| Climate / Weather | 1. Longer-Term and More Reliable Atmospheric Forecasts |
| Human Health and Security | 1. Heat Stress and Drought<br>2. Vector-Borne and Water-Borne Infectious Disease |
| Land-Use, Ecosystems, and Biodiversity | 1. Ecosystem Response (Variability and Change)<br>2. Agricultural and Ecosystem Productivity<br>3. Wild-Fires<br>4. Mineral Dust Production |

"…the SMAP mission is ready for "fast-track" towards launch as early as 2012, when there are few scheduled Earth missions. The readiness of the SMAP mission also enables gap-filling observations to meet key NPOESS community needs (soil moisture is "Key Parameter," see 4.1.6.1.6 in IORD-II Document)."

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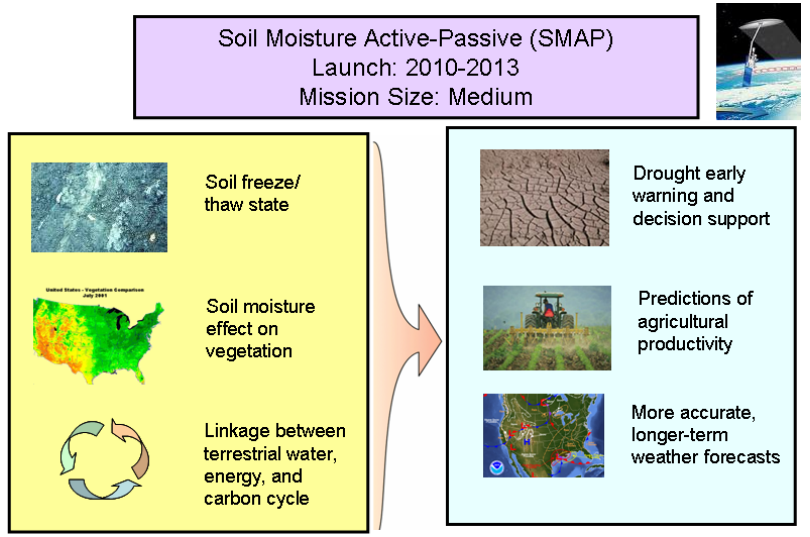
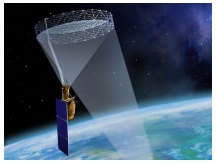
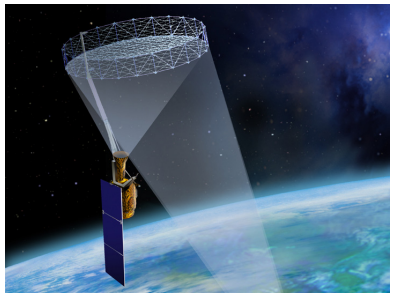
The cited SMAP applications can be accomplished with currently baselined flight instrument performance

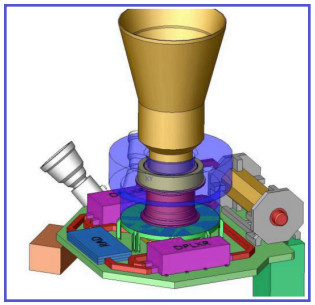




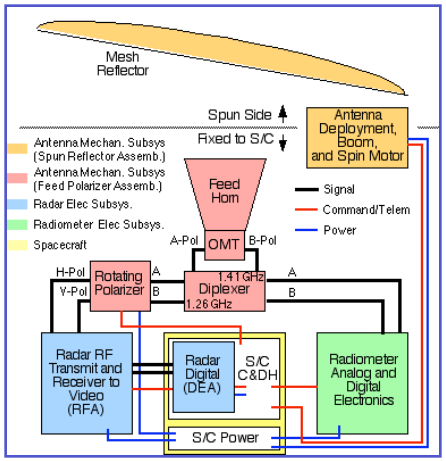
# SMAP Mission Concept



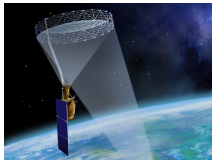
- Significant heritage from Hydros and Aquarius
  - Hydros risk-reduction performed during Phase A
    - Instrument
    - Spacecraft dynamics
    - Science algorithms
    - Ground data system
  - Heritage from Aquarius, particularly in RF Electronics



- L-band unfocused SAR and radiometer system with offset-fed 6-m deployable mesh reflector rotating about nadir axis
  - Single feed (dual-pol radar and polarimetric radiometer)
  - Conical scan, fixed incidence angle across 1000 km swath
  - Radar resolution: 1-3 km (Resolution degrades over center 30%)
  - Radiometer resolution: 40 km

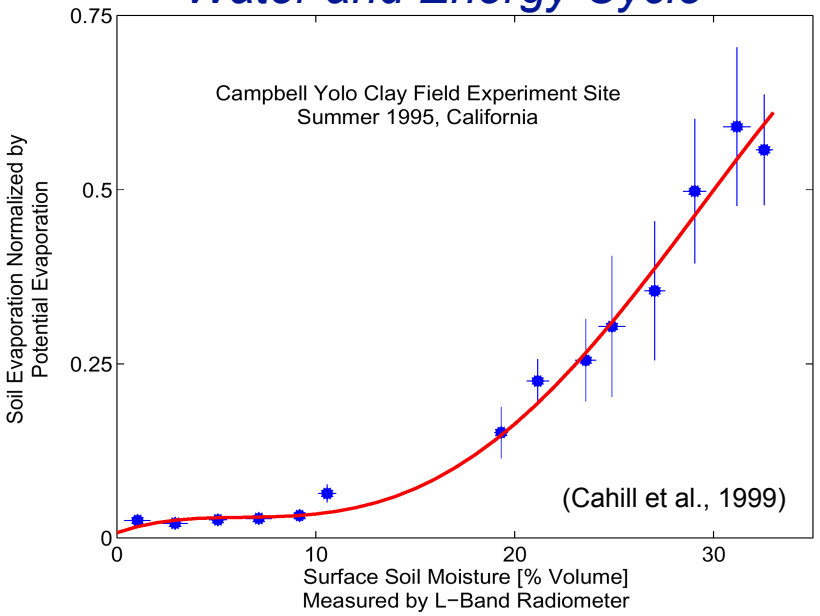



- Sun-synchronous dawn/dusk orbit
  - 3 Day revisit (2 days at high latitudes)
  - Three-year mission

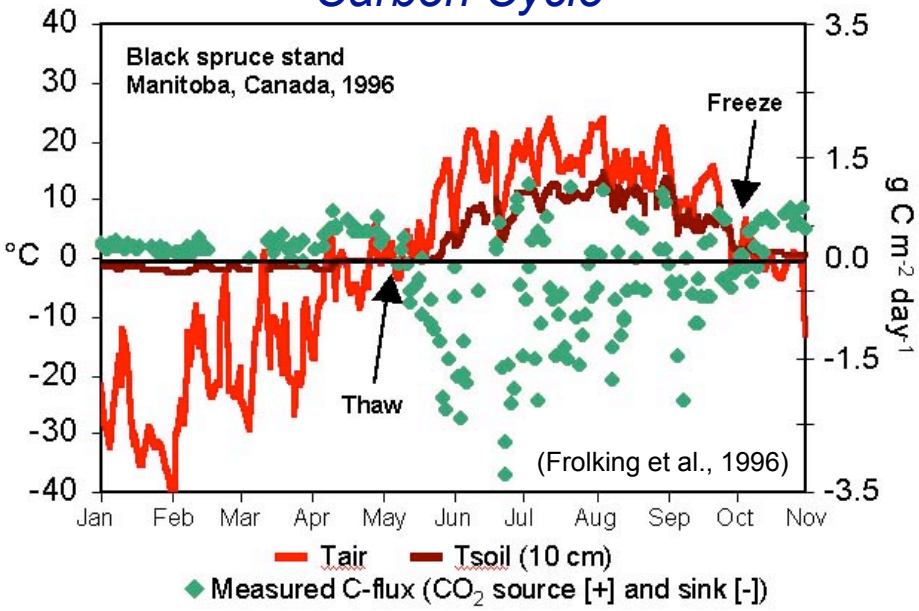


# Linking Water, Energy and Carbon Cycles

## *Water and Energy Cycle*




## *Carbon Cycle*



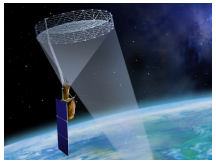

*Soil Moisture Controls the Rate of Continental Water and Cycles*

Do Climate Models Correctly Represent the Landsurface Control on Water and Energy Fluxes?

What Are the Regional Water Cycle Impacts of Climate Variability?

*Landscape Freeze/Thaw Dynamics Drive Boreal Carbon Balance*
*[The* Missing Carbon Sink *Problem].*

Are Northern Land Masses Sources or Sinks for Atmospheric Carbon?



# Flood and Drought Applications

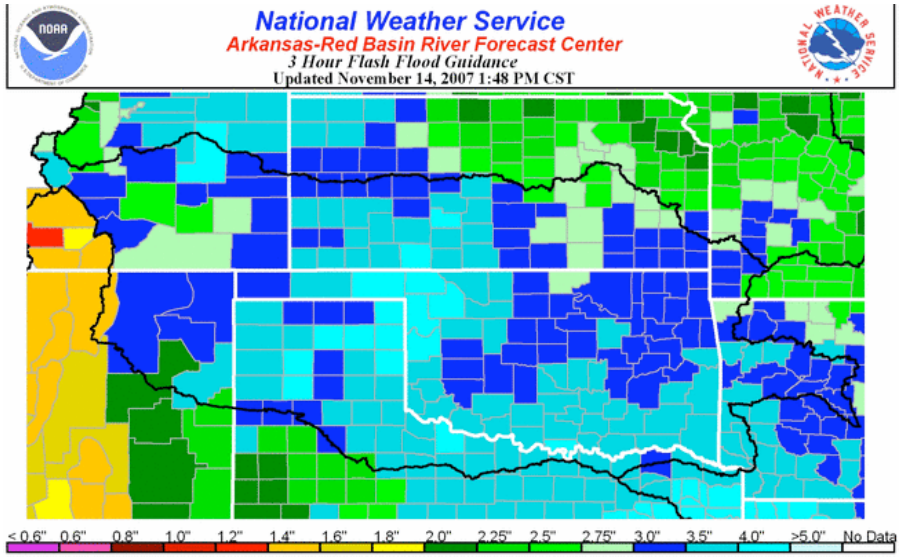
## SMAP Primary Science Objective

**Decadal Survey:**

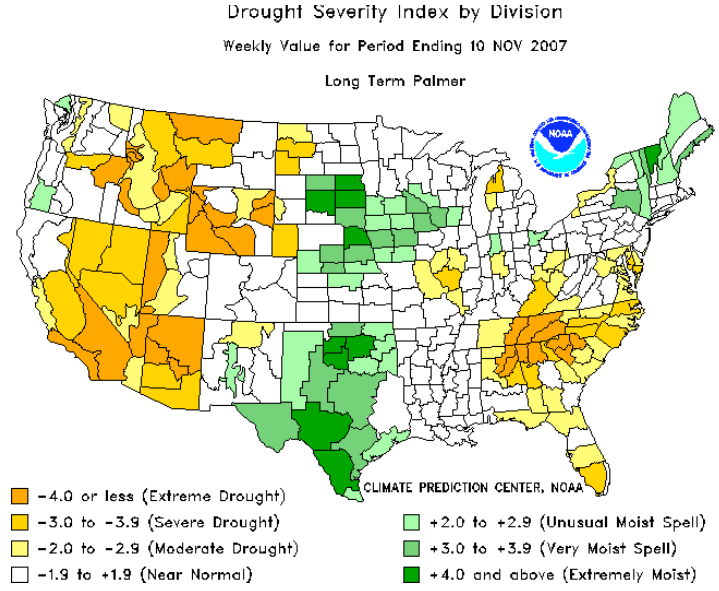
"…delivery of flash-flood guidance to weather forecast offices are centrally dependent on the availability of soil moisture estimates and observations."

"SMAP will provide realistic and reliable soil moisture observations that will potentially open a new era in drought monitoring and decision-support."

### Current NWS Operational Flash Flood Guidance (FFG)

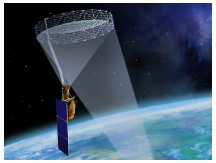



### Current Operational Drought Indices by NOAA and National Drought Mitigation Center (NDMC)



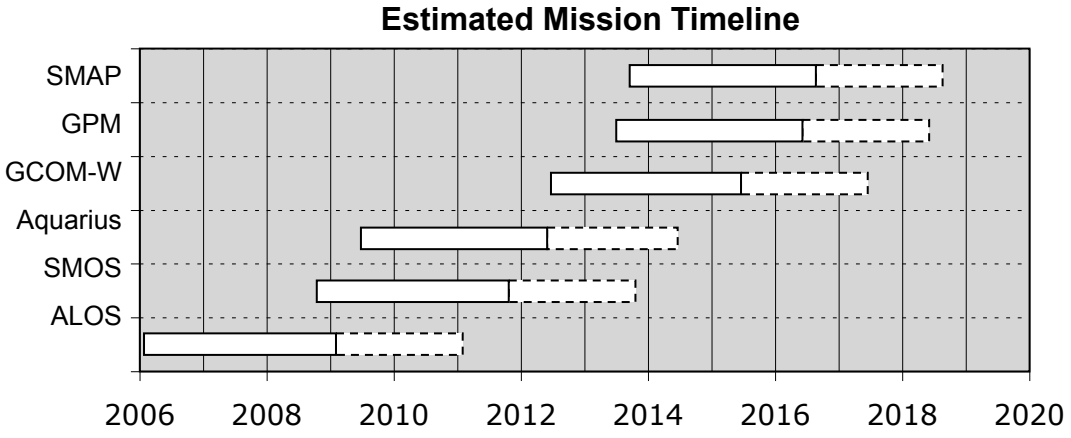

**<u>Current</u>: Empirical Soil Moisture Indices Based on Rainfall and Air Temperature ( By Counties or ~30 km )**

**<u>Future</u>: SMAP Soil Moisture Observations at 10 km**

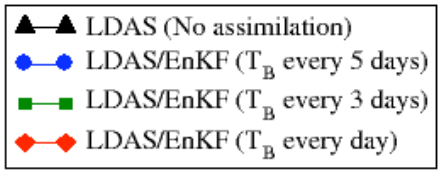


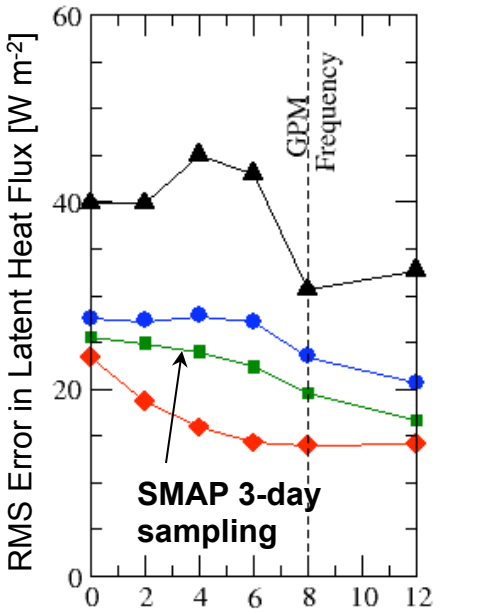
# SMAP Synergy With Other Missions/Applications

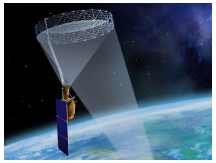
- SMAP provides continuity for L-band measurements of ALOS, SMOS, and Aquarius, and synergy with GPM and GCOM-W
- SMAP 1-3 km, 2-3 day global L-band multipolarization data provide potential for multiple new microwave applications
  - Similar to MODIS value for optical/ IR
- SMAP soil moisture and co-orbiting GPM precipitation data will improve surface flux estimates and flood forecasts (Crow et al., 2006)
- SMAP also benefits GPM by providing surface emissivity information for improved precipitation retrievals




***Potential reduction in GPM-estimated latent heat flux error by assimilation of SMAP soil moisture in land surface model (LDAS)***



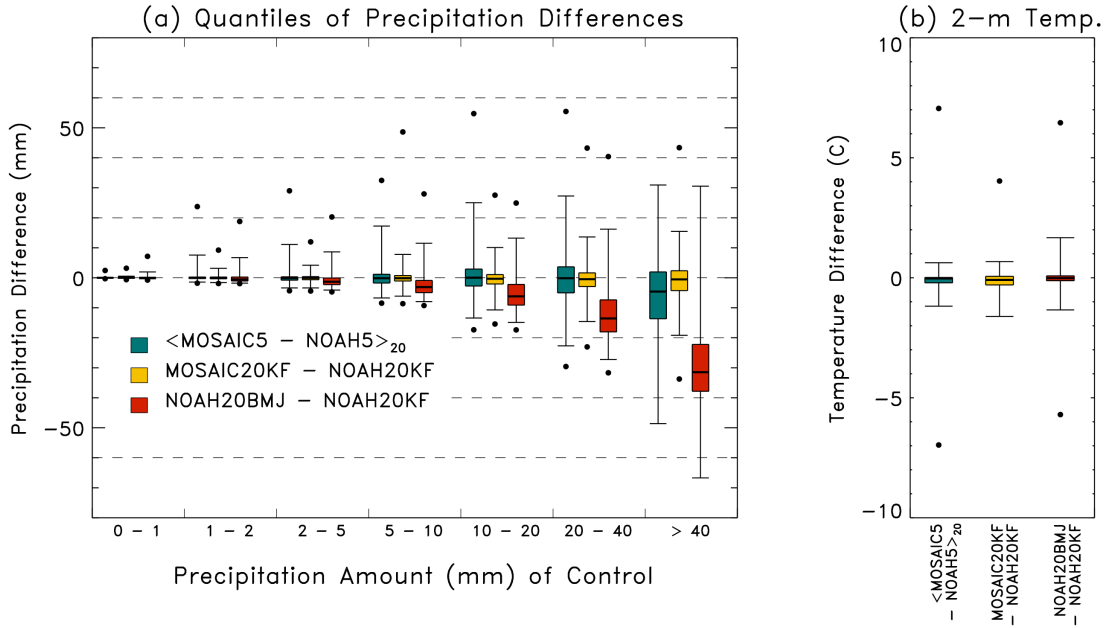





# Recent Results: NWP Skill

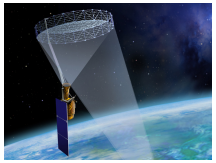
Sutton et al. (2007): Will Perturbing Soil Moisture Improve Warm-Season Ensemble Forecasts? A Proof of Concept, *Monthly Weather Review*, 134, 3174-3189.

**NOAA-FSL and NCAR Study**




"…changes to 5-km forecasts due to soil moisture differences were almost as large as the changes to 20-km forecasts due to using an alternate convective parameterization, previously determined to be a large source of uncertainty in ensemble forecasts…"

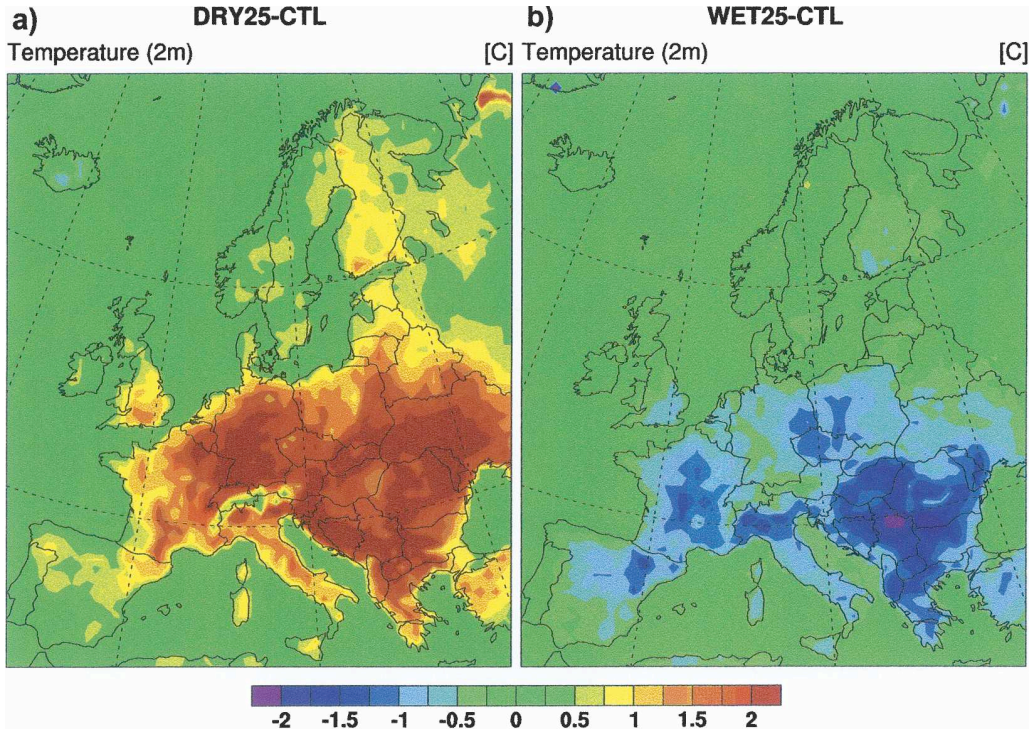
"…The results presented here suggest that short-term temperature and precipitation forecasts can indeed be changed as a consequence of changing the soil moisture…"



# Recent Results: Human Health

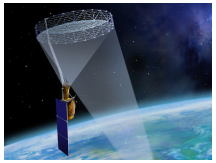
Fischer et al. (2007): Soil Moisture–Atmosphere Interactions during the 2003 European Summer Heat Wave, *Journal of Climate*, 20, 5089-5099.

**European heat wave cause 35,000 deaths, *New Scientist*, Oct. 10, 2003**



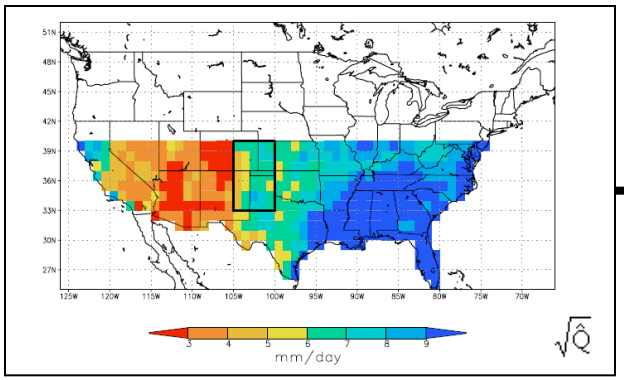

"…perturbed spring soil moisture shows that this quantity is an important parameter for the evolution of European heat waves…"

"…Simulations indicate that without soil moisture anomalies the summer heat anomalies could have been reduced by around 40% in some regions..."

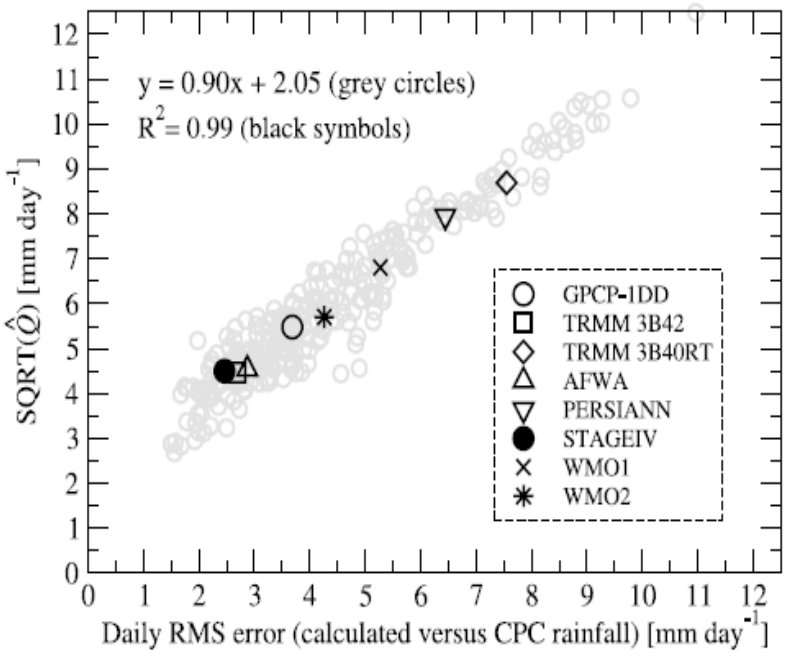


# Recent Results: Missions Synergy

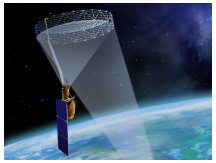
Crow et al. (2007): Estimating precipitation errors using spaceborne surface soil moisture retrievals, *Geophysical Research Letters*, 34.




Estimates of surface water cycle error based on assimilation of soil moisture observations

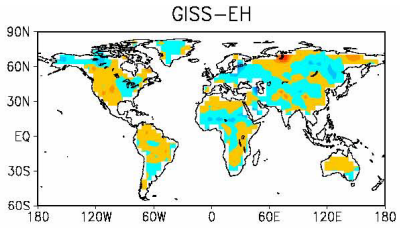


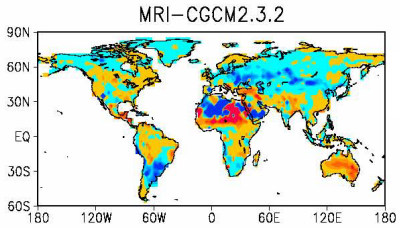

Errors in precipitation data products

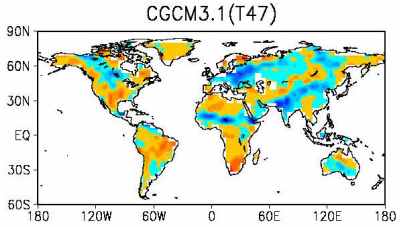


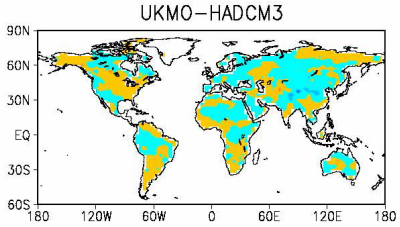
# Recent Results: Climate Change

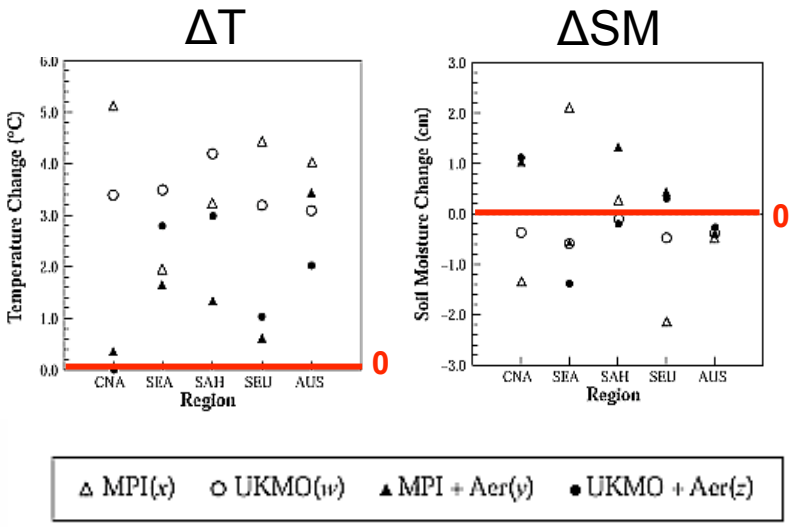
Li et al., (2007): Evaluation of IPCC AR4 soil moisture simulations for the second half of the twentieth century, *Journal of Geophysical Research*, 112.



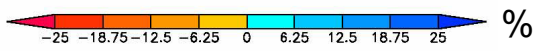



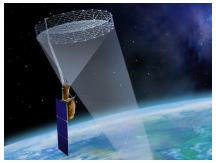




Projections of Summer Soil Moisture Change ΔSM: Disagreements in *Sign* Among IPCC AR4 Models





# Summary

Workshop Results and Follow-on Events:

- Independent costing of mission (within 5%)
- Presented Phase-A schedule to NASA HQ November 2007
- Plan for heritage capture from Aquarius
- Enhancements of radiometer for RFI detection and rejection
- Airborne instrument (PALS) developments (Array antenna demo during CLASIC'07; Incorporate RFI modules)
- Technical approach with heritage; Low cost risk; Multi-community research and operational impacts